

SPECIFICATION

METHOD AND APPARATUS FOR TREATING
SURFACE OF SUBSTRATE PLATE

BACKGROUND OF THE INVENTION

Field of the Art

This invention relates to a method and an apparatus for treating surfaces of substrate plates such as of liquid crystal display panels, semiconductor wafers, magnetic disks, optical disks and so forth, and more particularly to a method and an apparatus for washing or etching surfaces of substrate plates of glass, semiconductor, synthetic resin, ceramics, metal or composite material of these substances under irradiation of ultraviolet ray.

Prior Art

15 For instance, in the case of a TFT substrate which constitutes a
16 transparent substrate of a liquid crystal display panel, circuit patterns
17 including transparent electrodes are formed on its surface by the use of film
18 forming means. In the course of an LCD panel fabrication process, surfaces
19 of LCD panel substrate plates are processed through washing and etching
20 treatments. In treating substrate plates of this sort, it has been the general
21 practice to resort to the so-called wet process in which a treating liquid is
22 applied or sprayed on the surface of each substrate plate. However, recently
23 a dry process by irradiation of ultraviolet ray is increasingly employed for the

1 washing and etching treatments of various substrate plates.

2 In this regard, disclosed in Japanese Laid-Open Patent Application
3 2001-137800 is a process for treating substrate plates under irradiation of
4 ultraviolet ray. In this prior art process, while being transferred on a
5 conveyer means, substrate plates to be treated are passed through a lower
6 portion of a lamp house which is internally provided with a dielectric barrier
7 discharge lamp and supplied with a moistened inert gas, i.e., a mixture of
8 water vapor and an inert gas. The energy of irradiated ultraviolet ray from
9 the dielectric barrier discharge lamp act on organic contaminants which have
10 deposited on the surface of a substrate plate, breaking up chemical bonds in
11 organic contaminants and decomposing same into substances of low
12 molecular weight. In addition, the ultraviolet ray also act on water vapor in
13 the atmosphere and decompose water to produce a reducing active member
14 $[H\cdot]$ and an oxidative active member $[\cdot OH]$. As a consequence, the low
15 molecular weight substances which exist on the substrate surface are
16 converted into volatile substances through reduction or oxidation, by
17 reactions with the reductive and oxidative members $[H\cdot]$ and $[\cdot OH]$, and
18 released from the substrate surface. Thus, the substrate surface is cleaned
19 and at the same time improved in wettability.

20 In this connection, if oxygen exists in the atmosphere in which a
21 substrate plate is irradiated with ultraviolet ray from a dielectric barrier
22 discharge lamp, the energy of ultraviolet light ray is absorbed and attenuated
23 by oxygen. As a result, the capacity of decomposing organic contaminants on

1 the substrate surface is impaired to a considerable degree. Therefore, it is
2 extremely important to control the atmosphere of ultraviolet irradiation, more
3 specifically, to provide a dielectric barrier discharge lamp within a treating
4 chamber which is arranged to exclude oxygen from the atmosphere within the
5 chamber as much as possible. A mixture gas consisting of water vapor and
6 an inert gas and is supplied to the treating chamber as mentioned above, for
7 the purpose of generating the necessary active members [H·] and [·OH] on
8 and in the vicinity of a substrate plate in a concentrated manner. Further,
9 the internal pressure of the treating chamber needs to be maintained at an
10 elevated level in order to shield from air entrance and exit openings which are
11 provided at the upstream and downstream ends of the treating chamber.

12 Thus, it is an utmost importance to maintain, within a treating
13 chamber, a moistened inert gas atmosphere which is free of oxygen, in order
14 to effectively generate the above-mentioned active members, which contribute
15 the decomposition of organic contaminants on the surfaces of a substrate
16 plate under irradiation of ultraviolet ray from a dielectric barrier discharge
17 lamp, and to carry out a washing or other treatment to an extremely high
18 accuracy. In this regard, the above-mentioned prior art has a problem as
19 explained below.

20 Namely, as a substrate plate is transferred into a treating chamber
21 from outside, air is inevitably admitted into the treating chamber along with
22 the substrate plate. Especially, due to its viscosity, an air layer which exists
23 on the surface of the substrate plate remains stuck on the substrate surface

1 even after admission into the treating chamber. Therefore, if the substrate
2 plate in this state is advanced to an irradiating position under a dielectric
3 barrier discharge lamp in the treating chamber, considerable energy losses
4 are caused by the air layer which absorbs the energy of ultraviolet ray, even
5 in a case where the atmosphere in the treating chamber is strictly controlled.

6 **SUMMARY OF THE INVENTION**

7 With the foregoing situations in view, it is an object of the present
8 invention to provide a method and an apparatus for treating a surface of a
9 substrate plate under irradiation of ultraviolet ray emitted from a dielectric
10 barrier discharge lamp, suppressing energy loss of ultraviolet ray to a
11 minimum by removing oxygen from or in the vicinity of a treating surface of
12 the substrate plate prior to irradiation of ultraviolet ray from the dielectric
13 barrier discharge lamp.

14 According to the present invention, the above-stated objective is
15 achieved by the provision of a method for treating a surface of a substrate
16 plate under irradiation of ultraviolet ray emitted from a dielectric barrier
17 discharge lamp, which comprises the steps of: removing oxygen on and in the
18 vicinity of a treating surface of the substrate plate; supplying humidified inert
19 gas toward the substrate plate to humidify the treating surface and
20 surrounding atmosphere of the substrate plate; and irradiating the treating
21 surface of the substrate plate with ultraviolet ray from the dielectric barrier
22 discharge lamp.

23 According to a preferred form of the present invention, there is

1 provided a method for treating a surface of a substrate plate while being
2 transferred horizontally across a treating chamber under irradiation of
3 ultraviolet ray emitted from a dielectric barrier discharge lamp, which
4 comprises the steps of: removing oxygen or air on and in the vicinity of a
5 treating surface of the substrate plate by blasting a sweeping inert gas
6 thereto from a direction opposite to substrate transfer direction; supplying a
7 water vapor-containing humidified inert gas obliquely toward the substrate
8 plate in a forward direction in the substrate transfer direction to humidify the
9 treating surface and surrounding atmosphere of the substrate plate; and
10 irradiating the treating surface of the substrate plate with ultraviolet ray from
11 the dielectric barrier discharge lamp thereby cracking water vapor into a
12 reductive active member [H] and an oxidative active member [·OH] for
13 reaction with contaminant substances on the treating surface.

14 According to the present invention, there is also provided an apparatus
15 for treating a surface of a substrate plate under irradiation of ultraviolet ray,
16 comprising: a treating chamber provided in part of a path along which a
17 substrate plate is transferred horizontally by a conveyer means, the treating
18 chamber being provided with a dielectric barrier discharge lamp for
19 irradiating ultraviolet ray on a treating surface of the substrate plate; a
20 humidified inert gas feed means located at a position upstream of an
21 irradiating region of the dielectric barrier discharge lamp in substrate transfer
22 direction thereby to supply a humidified inert gas toward the treating surface
23 of the substrate plate; and an oxygen removing means located at a position

1 upstream of the humidified inert gas feed means in the substrate transfer
2 direction for removing oxygen from the treating surface and surrounding
3 atmosphere of the substrate plate.

4 The above and other objects, features and advantages of the present
5 invention will become apparent from the following particular description of
6 the invention, taken in conjunction with the accompanying drawings which
7 show by way of example some preferred embodiments of the invention.

8 Needless to say, the present invention is not limited to particular forms
9 shown in the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

11 In the accompanying drawings:

12 Fig. 1 is a schematic view of a dielectric barrier discharge lamp used in
13 a substrate treating apparatus according to the present invention;

14 Fig. 2 is an enlarged fragmentary view of the dielectric barrier
15 discharge lamp shown in Fig. 1;

16 Fig. 3 is a schematic view of a substrate treating apparatus adopted as
17 a first embodiment of the present invention;

Fig. 4 is a diagrammatic illustration of a nitrogen gas moisturizer;

19 Fig. 5 is a fragmentary sectional view of the substrate treating
20 apparatus shown in Fig. 3;

21 Fig. 6 is a schematic view of a substrate treating apparatus adopted as
22 a second embodiment of the present invention;

Fig. 7 is a fragmentary sectional view of a substrate treating apparatus.

1 adopted as a third embodiment of the invention;

2 Fig. 8 is a fragmentary sectional view of a substrate treating apparatus
3 adopted as a fourth embodiment of the present invention; and

4 Fig. 9 is a schematic view of a substrate washing and drying line
5 including a dry washing stage.

6 DESCRIPTION OF PREFERRED EMBODIMENTS

7 Hereafter, the present invention is described more particularly by way
8 of its preferred embodiments shown in the drawings. Firstly, schematically
9 shown in Figs. 1 and 2 is a dielectric barrier discharge lamp assembly
10 (hereinafter referred to simply as 'discharge lamp' for brevity) which is
11 employed on a substrate processing apparatus according to the present
12 invention.

13 In these figures, indicated at 1 is the discharge lamp. The discharge
14 lamp 1 is constituted by a quartz glass tube 4 of an annular shape, having
15 inner and outer tubes 2 and 3 which are both formed of quartz glass and
16 integrally with each other. Provided internally of the quartz glass tube 4 is a
17 hermetically closed discharge space 5. Securely fixed to the inner side of the
18 inner tube 2 is a metal electrode 6 consisting of a cylindrical metal sheet. On
19 the other hand, provided on the outer periphery of the outer tube 3 is a metal
20 mesh electrode 7. An ac power source 7 is connected between the metal
21 electrode 6 and metal mesh electrode 6. Further, a passage for a coolent fluid
22 (e.g., cooling water) is provided on the inner side of the inner tube 2 for
23 cooling the metal electrode 6.

1 A discharge gas is sealed in the quartz glass tube 4, so that, upon
2 applying an ac high voltage between the metal electrode 6 and the metal
3 mesh electrode 7, discharge plasma (dielectric barrier discharge) occurs
4 across a dielectric between the inner and outer tubes 2 and 3, and, by this
5 discharge plasma, atoms of the discharge gas are excited into a plasma
6 discharge state. Plasma discharge emission takes place as the discharge gas
7 atoms in the plasma state return to a normal state. At this time, the
8 emission spectrum varies depending upon the nature of the discharge gas
9 which is sealed in the quartz glass tube 4. In the case of a xenon gas (Xe), for
10 example, monochrome light having a center wavelength at 172nm is emitted.
11 The metal electrode 6 functions as a reflector plate, while the metal mesh
12 electrode 7 functions substantially as a transparent electrode. Therefore,
13 ultraviolet light of short wavelength is irradiated from the side of the outer
14 tube 3. In this instance, for example, the pressure of charged xenon gas is
15 approximately 350torr.

16 Schematically illustrated in Fig. 3 is an apparatus for dry-washing
17 transparent substrates of LCD panels by the use of the discharge lamp 1 as
18 described above. In this figure, indicated at 10 is a substrate plate under a
19 dry-washing treatment. For example, the substrate 10 consists of a thin
20 plate of glass, semiconductor, synthetic resin, ceramics, metal and so forth,
21 and of a rectangular or circular shape in plan view. The substrate 10 is
22 supported on a transfer means, for example, on a roller conveyer 11 (e.g.,
23 consisting of a plural number of rollers on rotational shafts which are

1 arranged in a predetermined pitch in the direction of transfer), and thereby
2 transferred in the direction indicated by an arrow in the same figure while
3 receiving a dry-washing treatment on its surface or surfaces. For this
4 purpose, a treating chamber 12 of the washing apparatus is located in a
5 predetermined position in the path of transfer by the roller conveyer 11. The
6 treating chamber 12 is provided with an entrance opening 12a and an exit
7 opening 12b in its walls at its upstream and downstream ends for admitting
8 untreated substrate plates 10 and for sending out treated substrate plates 10
9 therethrough, respectively. The entrance and exit openings 12a and 12b are
10 arranged to have a minimum open area which permits at least passage of the
11 substrate plates 10 and which can keep the substrate plates 10 out of
12 contact with walls of the entrance and exit openings 12a and 12b even if the
13 substrates 10 are vibrated while being transferred by the conveyer 11.

14 Provided on top of the treating chamber 12 is a lamp house 13 having
15 the discharge lamp 1 installed therein. The lamp house 12 is arranged to
16 internally provide a hermetically closed space, and a window pane 14 made of
17 quartz glass is fitted on the bottom side of the lamp house 13 under the
18 discharge lamp 1. Further, a reflector member 15 in the form of a concave
19 mirror or the like is provided over the discharge lamp 1, so that ultraviolet ray
20 from the discharge lamp 1 is reflected in downward directions. A nitrogen gas
21 feed pipe 16 is connected to the lamp house 13 for the purpose of preventing
22 attenuation of ultraviolet ray from the discharge lamp 1. More specifically,
23 through the nitrogen gas feed pipe 16, nitrogen gas (N₂ gas) is fed into the

1 lamp house 13 as an inert gas to provide an oxygen-free space therein. In
2 this instance, the nitrogen gas is dry nitrogen gas or wet nitrogen gas
3 containing water vapor.

4 Further, wet nitrogen gas, which is moistened with water vapor, is also
5 supplied as an inert gas medium toward a treating surface of the substrate
6 plate 10. For this purpose, a wet nitrogen gas feed nozzle 17 is opened into
7 the treating chamber 12. This wet nitrogen gas feed nozzle 17 is located on
8 an upstream side of the lamp house 13 in the transfer direction of the
9 substrate plate 10, and is at least of a width which is sufficient for covering
10 the entire width of the substrate plate 10. In order to spurt the wet nitrogen
11 gas toward the substrate plate 10 obliquely from above, a lower end portion of
12 the wet nitrogen gas feed nozzle 17 is angularly bent through a
13 predetermined angle.

14 In this instance, wet nitrogen gas which is moistened with water vapor
15 is supplied through the wet nitrogen gas feed nozzle 17. For this purpose,
16 the wet nitrogen gas feed nozzle 17 is connected to a nitrogen gas humidifier.
17 Shown in Fig. 4 is an example of a nitrogen gas humidifier construction
18 which can serve for the purpose of the present invention. In this figure,
19 indicated at 20 is a nitrogen gas tank which is a source of nitrogen gas. A
20 wet nitrogen gas feed pipe 21 from the tank 20 is bifurcated into two branch
21 pipes 21a and 21b. A first branch pipe 21a is connected to a mixer 24
22 through a flow regulator valve 22 and a flow meter 23.

23 On the other hand, a second branch pipe 21b is connected to and

1 opened into a pure water tank 27 at a submerged position, through a flow
2 regulator valve 25 and a flow meter 26. The submerged portion of the second
3 branch pipe 21b is provided with a multitude of fine pores for releasing
4 nitrogen gas into pure water of the tank 27. As bubbles of nitrogen gas climb
5 up toward the surface of pure water in the tank 27, water vapor is generated
6 to produce moistened nitrogen gas, that is, a humidified neutral gas. The
7 moistened nitrogen gas thus produced is led into the mixer 24 and mixed
8 with nitrogen gas from the first branch pipe 21a to adjust the moisture
9 concentration in the inert gas. The above-mentioned nitrogen gas feed nozzle
10 17 which is projected into the chamber 12 is connected from the mixer 24,
11 and provided with a pressure regulator valve 29 thereby to adjust the
12 pressure of humidified nitrogen gas to be supplied to the chamber 12.

13 As an oxygen removing means, a nitrogen gas nozzle 30 is projected
14 into the treating chamber at a position on the upstream side of the position of
15 the wet nitrogen gas feed nozzle 17 in the transfer direction of the substrate
16 plate 10. More specifically, the nitrogen gas injection nozzle 30 is located
17 between the wet nitrogen gas feed nozzle 17 and the entrance opening 12a of
18 the treating chamber 12, and provided with a spout mouth, which is of a
19 sufficient length for covering the entire width of the substrate plate 10 and
20 adapted to spurt nitrogen gas immediately downward toward the substrate
21 plate 10. Front and rear lips of the spout mouth of the nitrogen gas injection
22 nozzle 30 are diverged or spread apart in forward and rearward directions, a
23 gas distribution guide member 31 is provided between the front and rear lips

1 of the nozzle mouth. As indicated by arrows in Fig. 5, the dry nitrogen gas
2 which flows through the nitrogen gas injection nozzle 30 is divided by the gas
3 distribution guide member 31 into two separate streams, one stream being
4 guided in the rearward direction toward the entrance opening 12a of the
5 treating chamber 12 to fall on an incoming substrate plate portion obliquely
6 from above. The other streams of nitrogen gas are guided forward in the
7 transfer direction of the substrate plate 10. For guiding streams of dry
8 nitrogen gas in two different directions in this manner, the gas distribution
9 guide member 31 is provided with inclined guide surfaces 31a and 31b which
10 diverge away from each other in the downward direction.

11 Further, an exhaust pipe 33 is connected to a bottom portion of the
12 treating chamber 12 at a position under and at a downstream side of the
13 lamp house 13. The other end of the exhaust pipe 33 is connected to a
14 suction pump or a negative pressure generating means so that a negative
15 pressure or suction force prevails in the exhaust pipe 33. Therefore, the
16 gases which are supplied into the treating chamber 12 through the nitrogen
17 gas injection nozzle 30 and the wet nitrogen gas feed nozzle 17 are constantly
18 urged to flow out through the exhaust pipe 33 without lingering in the
19 treating chamber 12. Namely, the gases are constantly circulated through
20 the treating chamber 12.

21 Intrusion of air from outside can be prevented by elevating the internal
22 pressure of the treating chamber 12 above the atmospheric pressure.
23 However, in order to blocking intrusion of air in a more assured manner,

1 upper and lower suction boxes 34a and 34b are provided opposingly on the
2 outer side of the entrance openings 12a of the treating chamber 12 as an air
3 shielding means. The upper and lower suction boxes 34a and 34b are
4 connected to suction pipes 35a and 35b, respectively, and spaced apart from
5 each other by a gap space which permits passage of the substrate plate 10.
6 On the other hand, an air curtain box 36 is provided on the outer side of the
7 exit opening 12b of the treating chamber 12 to serve as an air shield means
8 for generating downward air streams constantly along outer surfaces of the
9 treating chamber 12 and thereby forming an air shield across the exit
10 opening 12b. The shielding air streams are blocked by the substrate plate 10
11 while the latter is being passed through the exit opening 12b. However, on
12 that occasion, the exit opening 12b is substantially closed by the substrate
13 plate 10 which is moving in the outward direction, so that intrusion of air
14 from outside can be prevented securely as long as the internal pressure of the
15 treating chamber 12 is maintained at a slightly elevated level as compared
16 with the atmospheric or ambient pressure.

17 Thus, by supply of dry nitrogen gas to the lamp house 13 with the
18 discharge lamp 1 through the nitrogen gas feed pipe 16, an oxygen-free
19 atmosphere is created within the closed internal space of the lamp house 13.
20 In the meantime, through the nitrogen gas injection nozzle 30, dry nitrogen
21 gas is also injected into the treating chamber 12, in which a substantially
22 oxygen-free and nitrogen gas-prevailing atmosphere is maintained because
23 the entrance and exit openings 12a and 12b are shielded by the air shielding

1 suction boxes 34a and 34b and the air curtain box 36, respectively, to
2 prevent intrusion of air. Besides, the wet nitrogen gas feed nozzle 17 is also
3 located in the treating chamber 12. Water vapor in the wet nitrogen gas
4 which is supplied through the wet nitrogen gas feed nozzle 17 should not be
5 allowed to prevail in the treating chamber 12. For this purpose, it is
6 preferred to turn off injection of wet nitrogen gas through the nozzle 17 when
7 no substrate plate 10 exists within the treating chamber 12. However, in a
8 case where the exhaust pipe 33 is opened in a vertically confronting position
9 with respect to the wet nitrogen gas feed nozzle 17, wet nitrogen gas is almost
10 immediately discharged through the exhaust pipe 33 instead of dwelling in
11 the treating chamber 12 even if it is injected continuously.

12 Through the entrance opening 12a, the substrate plate 10 on the roller
13 conveyer 11 is admitted into the atmosphere within the treating chamber 12
14 which is controlled in the manner as described above. Atmospheric air
15 prevails outside the treating chamber 12. Therefore, upon admission into the
16 treating chamber 12, air still exists on or in the vicinity of surfaces of the
17 substrate plate 10 and, due to its viscosity, tends to remain stuck on
18 substrate surfaces even after the substrate plate 10 has been admitted into
19 the treating chamber 12. Therefore, air which exists on or in the vicinity of
20 substrate surfaces needs to be replaced by nitrogen gas, in an initial oxygen
21 removing stage as described below.

22 Namely, as soon as the substrate plate 10 is admitted into the treating
23 chamber 12 through the entrance opening 12a, dry nitrogen gas is sprayed

1 on a treating surface of the substrate plate 10 from the nitrogen gas injection
2 nozzle 30. After being switched in flow direction and rectified by the guide
3 surface 31a of the gas distribution guide member 31, dry nitrogen gas is
4 sprayed on the treating surface of the substrate plate 10 obliquely from above
5 and allowed to flow along the treating surface of the substrate plate 10.
6 Because of the suction force of the air shielding suction boxes 34a which is
7 provided on the outer side of the entrance opening 12a, the velocity of the dry
8 nitrogen gas flow on and along the treating plate 10 is increased to such a
9 degree as to scrape off an air layer which has remained on the surface of the
10 substrate plate 10 since admission into the treating chamber 12, pushing
11 away air through the entrance opening 12a. As a consequence, air on the
12 treating surface of the substrate plate 10 is removed and replaced by dry
13 nitrogen gas which is free of oxygen.

14 Further to the replacement of air, wet nitrogen gas which is injected
15 through the wet nitrogen gas feed nozzle 17 is supplied toward the substrate
16 plate 10 to wet the treating surface as well as the atmosphere in the vicinity
17 of the substrate plate 10. In this humidifying stage, wet nitrogen gas is
18 injected forward in the transfer direction of the substrate plate 10 and
19 showered on the latter obliquely from above. Consequently, wet nitrogen gas
20 is supplied to the treating surface of the substrate plate 10 which is now free
21 of oxygen, as a result of replacement by nitrogen gas in the preceding stage.
22 Thus, the treating surface of the substrate plate 10 is held in an oxygen-free
23 atmosphere consisting of a mixture of an inert gas and water vapor.

1 Further, as the substrate plate 10 is advanced to a position under the
2 window 14 of the lamp house 13, the treating surface of the substrate 10 is
3 irradiated with short wavelength ultraviolet ray from the discharge lamp 1 for
4 a washing treatment. This is a treating stage. At this time, in order to
5 suppress attenuation of ultraviolet ray from the discharge lamp 1 as much as
6 possible, it is preferred to narrow the gap space between the treating surface
7 of the substrate plate 10 and the glass 10 of the irradiation window to a
8 minimal value. Nevertheless, it is necessary to keep the treating surface of
9 the substrate plate 10 out of contact with the window pane 14 while it is
10 transferred by the roller conveyer 11. Considering that the substrate plate 10
11 is inevitably vibrated to a certain degree while being transferred on the
12 conveyer 11, the substrate plate 10 should be spaced from the window pane
13 14 by a minimum gap space which will be necessary to keep the substrate
14 plate 10 out of contact with the window pane 14 despite its vibrations.

15 Due to the existence of a mixed fluid of nitrogen gas and water on and
16 in the vicinity of the treating surface of the substrate plate 10, water is
17 cracked under irradiation of ultraviolet light from the discharge lamp 1 into a
18 reductive active member $[H \cdot]$ and an oxidative active member $[\cdot OH]$. Besides,
19 under irradiation of short wavelength ultraviolet light, organic contaminants
20 which have deposited on the surface of the substrata 10 are decomposed into
21 products of lower molecular weights. Further, the low molecular weight
22 products resulting from the decomposition of organic contaminants are
23 subjected to reducing and oxidative reactions with the cracked active

1 members of water. More specifically, not only oxidative reactions with the
2 oxidative active member [$\cdot\text{OH}$] but also reducing reactions with reductive
3 active member [$\text{H}\cdot$] take place on or in the vicinity of the surface of the
4 substrate 10 to convert decomposed organic substances into volatile
5 substances quickly in an assured manner.

6 In addition, the gas distribution guide member 31 of the nitrogen gas
7 injecting nozzle 30 is provided with the guide surface 31b which is arranged
8 to direct nitrogen gas forward in the substrate transfer direction, while the
9 wet gas feed nozzle 17 is arranged to form wet nitrogen gas streams also in
10 the substrate transfer direction. Therefore, volatile substances which are
11 generated under irradiation of ultraviolet ray are drifted away from the
12 irradiating region under the lamp house 13 and urged to leave the treating
13 chamber quickly through the exhaust pipe 33. Accordingly, wet nitrogen gas
14 containing water vapor is constantly supplied to the irradiating region under
15 the lamp house 13.

16 By the dry washing treatment as described above, organic
17 contaminants are removed from the surface of the substrate 10. In addition,
18 the substrate surface becomes to have a smaller contact angle as a result of
19 irradiation of short wavelength ultraviolet ray in the presence of water vapor.
20 A substrate surface with a smaller contact angle shows improved wettability
21 in a subsequent wet washing treatment, for example, in a shower washing
22 treatment, making it possible to wash away organic contaminants more
23 readily and completely from its surfaces. Accordingly, the substrate 10 can

1 be washed into an extremely clean state. For instance, the above-described
2 dry-washing treatment may be carried out for the purpose of improving
3 surface conditions of substrates in a stage preparatory to application of a
4 liquid developer or the like.

5 As described above, a substantially oxygen-free atmosphere is
6 maintained in the internal space of the treating chamber 12. Therefore, if
7 desired, the window pane of the lamp house may be removed to provide an
8 open lamp house 113 as in the case of a modification shown in Fig. 6. The
9 window pane of glass needs to be replaced at a certain frequency because it is
10 deteriorated in the long run by repeated transmissions of ultraviolet ray.
11 Namely, the lamp house without a window pane can contribute to make the
12 maintenance and service easily by lowering the frequency of parts
13 replacements. In the case of the hermetically closed lamp house, there is no
14 need for constantly feeding nitrogen gas thereto through the nitrogen gas feed
15 pipe. However, in the case of the open lamp house 113 which is opened to
16 the treating chamber on its bottom side as shown in Fig. 6, it is necessary to
17 supply dry nitrogen gas constantly to the treating chamber through a
18 nitrogen gas feed pipe 116 thereby to prevent wet nitrogen gas, which is
19 supplied through the wet nitrogen gas feed nozzle 17, from entering the lamp
20 house 113.

21 Shown in Figs. 7 and 8 are alternative examples of the oxygen
22 removing means which can be suitably employed in the present invention. In
23 this regard, depending upon the type of the substrate transfer mechanism,

1 oxygen can be removed from the surface of a substrate plate by bringing a
2 sweeper plate or roller into contact therewith.

3 Shown in Fig. 7 is a purging gas injection nozzle 230 which is provided
4 within a treating chamber 212 in the vicinity of and at least on the upper side
5 of an entrance opening 212a. If desired, a similar purging gas injection
6 nozzle 230 may be provided also on the lower side of the entrance opening
7 212a.

8 In this instance, the sweeping gas injection nozzle 230 is provided with
9 a tubular nozzle body 231 of a length which is sufficient for covering the
10 entire width of a substrate plate 10. Formed internally of the nozzle body 231
11 is a pressure chamber 232 to which an inert gas feed pipe is connected.
12 Further, the nozzle body 231 is provided with a slit mouth 234 at and along
13 one side thereof to spurt an inert gas toward a substrate plate 10 on the
14 roller conveyer 11, for example, at an angle of incidence of approximately 30
15 to 40 degrees with respect to the treating surface of the substrate 10.

16 With the arrangements as described above, by an inert gas (e.g.,
17 nitrogen gas) which is spurted out under high pressure from the gas injection
18 nozzle 230, air which may exist on or in the vicinity of a treating surface of
19 the substrate plate 10 is blasted away to remove oxygen from the treating
20 atmosphere as indicated by an arrow in Fig. 7. A major part of the inert gas
21 which is injected by the gas injection nozzle 230 is discharged from the
22 treating chamber 212. In this case, it is preferable to connect another inert
23 gas feed pipe (not shown) to the treating chamber 212 and to supply thereto

1 an inert gas for preventing pressure drops in the treating chamber 212, that
2 is, for maintaining the treating chamber 212 at a higher pressure level than
3 the ambient atmosphere.

4 Further, shown in Fig. 8 is a gas injection nozzle 330 which is similar
5 to the above-described gas injection nozzle 230 in construction. In this case,
6 the gas injection nozzle 330 is located in the treating chamber such that its
7 slit mouth 334 is directed toward a gap space between a substrate plate and
8 an entrance opening 312a of a treating chamber 312. The sweeping gas
9 which is injected by the gas injection nozzle 330 is entirely discharged from
10 the treating chamber, so that it is not necessarily required to be an inert gas.
11 For example, in this case even air can be used as a sweeping gas. Besides,
12 due to a negative pressure which is developed at the entrance opening 12a as
13 a result of injection of the purging gas, the inert gas filling the treating
14 chamber 312 is pulled toward and carried away together with sweeping air
15 streams leaving the treating chamber 312. Therefore, an oxygen-containing
16 air layer on the surface of the substrate plate 10 is swept away and replaced
17 by an inert gas which prevails in the treating chamber 312.

18 In the same manner as explained in the foregoing embodiments, the
19 contact angle of the substrate surface becomes smaller after removal of
20 organic contaminants by the above dry washing treatment. Subsequent to
21 the dry washing treatment, the substrate plate 10 is passed through a
22 number of stages for further treatments, for example, in an LCD panel
23 fabrication process as diagrammatically shown in Fig. 9.

1 Indicated at 50 in Fig. 9 is the above-described dry washing stage, and
2 at 51 is a wet washing stage following the dry washing treatment. The wet
3 washing stage 51 is followed by a drying stage 52. By these treatments,
4 surfaces of the substrate plate 10 are cleaned completely.

5 In the wet washing stage 51, inorganic contaminants on the surfaces of
6 the substrate plate 10 are washed away in a shower of ultrasonically
7 activated pure water which is poured through shower heads 51a. Needless to
8 say, this wet washing stage may employ a different type of washing in place of
9 the shower type, for example, may employ a scrubbing type of washing by the
10 use of scrubbing brushes or a dip-in type of washing by immersion in an
11 ultrasound washing bath, or may employ a combination of different types of
12 washing. Inorganic as well as organic contaminants are removed virtually
13 completely in this wet washing stage until surfaces of the substrate plate 10
14 are put in an extremely clean state. In the following drying stage 52, the
15 washed substrate plate can be dried by spin drying, or by air knife effects,
16 that is, by the use of an air knife nozzle 52a as shown by way of example in
17 the drawing. By passage through these washing and drying stages, the
18 substrate plate 10 is completely cleaned and dried.

19 Further, in some cases, the dry washing treatment may come after wet
20 washing and drying treatments. For example, in the case of a pretreatment
21 preceding to application of a developer solution or the like, a substrate plate
22 10 is wet-washed in the first place to remove contaminant substances from
23 its surfaces, followed by drying and dry washing treatments. By the last dry

washing treatment, the surface conditions of the substrate plate are improved to have a smaller contact angle, ensuring uniform application of a developer solution in a succeeding stage.

As clear from the foregoing description, according to the present invention, in a dry washing treatment of a substrate plate under irradiation of ultraviolet ray, accuracy and washing effects by irradiated ultraviolet ray are improved to a remarkable degree by maintaining an oxygen-free atmosphere is maintained in an irradiating region withing a treating chamber.